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(54) **Pedal force responsive engine controller.**

(57) An engine controller monitors the force applied to the accelerator pedal and normal engine operating conditions during which the force applied to the accelerator pedal is normally zero and provides for normal engine operation if these conditions exist. When the force applied to the accelerator pedal is zero and none of the normal engine operating conditions at which the force applied to the accelerator pedal is normally zero exist, the engine is forced into a back-up control mode.

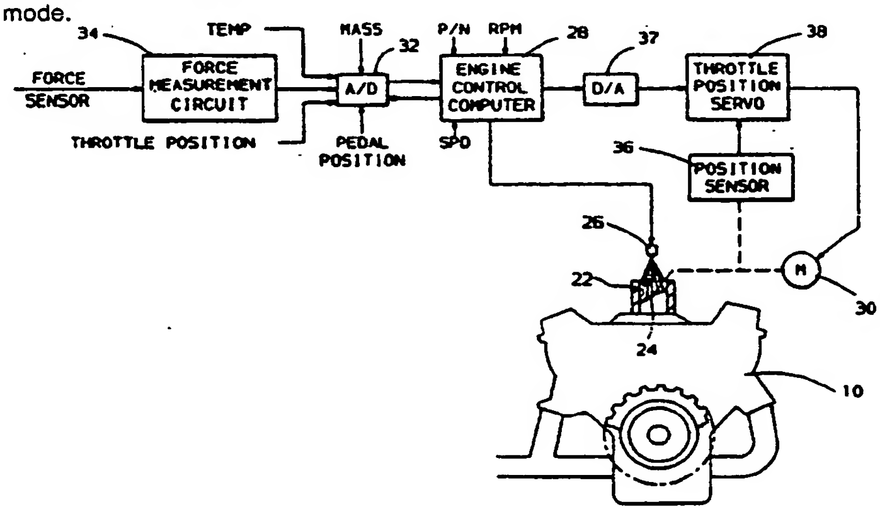

FIG.2

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PEDAL FORCE RESPONSIVE ENGINE CONTROLLER

This invention relates to an engine controller which is accelerator pedal force responsive and, more particularly, to an engine controller responsive to an applied force to the vehicle accelerator pedal and to predetermine engine operating conditions to establish the engine control either in a normal operating mode or in a back-up operating mode.

Engine controllers responsive to engine operating conditions for enabling back-up control are known. One such arrangement includes a drive by wire controller that monitors the force applied to the accelerator pedal and forces an engine idle mode if the applied force is zero. This form of apparatus is illustrated in US Patent No. 4,640,248.

This invention recognizes that there are valid engine operating modes in which the force applied to the accelerator pedal is zero. Accordingly, it would not be desirable to establish a back-up operating mode in response to these operating conditions. For example, when a vehicle is being operated in a cruise control mode to maintain the vehicle speed at a selected value, the force on the accelerator pedal is zero. Similarly, when the internal combustion engine is operating in a closed loop idle speed control mode, the force applied to the accelerator pedal is zero. In each case, it would not be desirable to establish back-up control for the engine operation.

An engine controller in accordance with the present invention is characterised by the features specified in the characterising portion of claim 1.

This invention monitors the force applied to the accelerator pedal and normal engine operating conditions during which the force applied to the accelerator pedal is normally zero and provides for normal engine operation if these conditions exist. However, when the force applied to the accelerator pedal is zero and none of the normal engine operating conditions at which the force applied to the accelerator pedal is normally zero exist, the engine is forced into a back-up control mode to provide for fail-safe engine operation.

The invention is now described, by way of example, with reference to the following description of a preferred embodiment of the invention, and the accompanying drawings, in which:-

Figure 1 is a schematic diagram of an accelerator pedal in a vehicle drive by wire apparatus incorporating the principles of this invention;

Figure 2 is a diagram of the internal combustion engine and engine controller incorporating the principles of this invention; and

Figures 3 and 4 are computer flow diagrams illustrating the operation of the engine controller of Figure 2 in carrying out the principles of this invention.

Referring to Figures 1 and 2, an internal combustion engine 10 is controlled by a vehicle operator by application of force to an accelerator pedal 12 tending to rotate the accelerator pedal 12 about a pivot 14 to an off idle position in opposition to a return force exerted by a spring 16 tending to rotate the accelerator pedal 12 to an engine idle position. The accelerator pedal 12 rotates from its engine idle position to an off idle position that is dependent upon the magnitude of the vehicle operator applied force opposing the force of the spring 16.

The position of the accelerator pedal 12 is used by an engine controller illustrated in Figure 2 to adjust the cylinder charge of the internal combustion engine 10. In this embodiment, the position of the accelerator pedal 12 represents a desired fuel injection amount. In this case, the engine controller controls engine fuel injectors to inject the desired amount and then adjust the mass airflow into the internal combustion engine 10 to achieve a desired air/fuel ratio. In another embodiment, the position of the accelerator pedal 12 may represent a desired mass airflow amount. In this case, the engine controller adjusts the mass airflow into the internal combustion engine 10 to equal the desired flow and controls the quantity fuel injected into the internal combustion engine 10 to achieve the desired air/fuel ratio.

To provide a measure of the position of the accelerator pedal 12 representing the operator input command, a linear potentiometer 18 (position sensing means) is positioned so as to be actuated by rotation of the accelerator pedal 12 about the pivot 14. The output of the linear potentiometer 18 is utilized in the engine controller of Figure 2 to control the air and fuel input to the internal combustion engine 10. In addition, a force sensor 20 (force sensing means), which may take the form of a resistive strain gauge, is carried by the accelerator pedal 12 so as to provide an output that is a measure of the force applied to the accelerator pedal 12 by the vehicle operator in opposition to the spring force on the accelerator pedal 12 by the spring 16.

Referring to Figure 2, air and fuel are drawn into the internal combustion engine 10 through a throttle bore 22 having a throttle blade 24 positioned therein to control the airflow into the internal combustion engine 10. Fuel is injected into the throttle bore 22 at a position above the throttle blade 24 via a fuel injector 26. In this embodiment, the quantity of fuel injected by the fuel injector 26

is commanded by the accelerator pedal 12 and the throttle blade 24 is positioned to control the airflow into the internal combustion engine 10 to achieve a desired air/fuel ratio.

The control of the fuel injector 26 and the throttle blade 24 is accomplished by the engine controller, the primary element of which is an engine control computer 28 in the form of a standard digital microprocessor having an operating program stored therein whose step-by-step execution controls the fuel injector 26 and positions the throttle blade 24 in accordance with the principles of this invention.

In general, the engine control computer 28 issues timed pulses to the fuel injector 26 to inject fuel into the internal combustion engine 10 based on the position of the accelerator pedal 12 and controls the position of the throttle blade 24 via a servomotor 30 to achieve the airflow producing the desired air/fuel ratio. The engine control computer 28 is a conventional automotive computer including memories, central processing unit, input/output circuits and a clock and may be programmed to achieve the functions set forth in the flow diagrams of Figures 3 and 4 by the normal exercise of skill in the art.

The measurements of various analogue signals are provided to the engine control computer 28 via an analogue-to-digital circuit 32. These signals include the output of the linear potentiometer 18 representing the position of the accelerator pedal 12, the output of a conventional mass airflow sensor (not illustrated) measuring the mass airflow into the internal combustion engine 10, the output of a force measurement circuit 34 representing the force sensed by the force sensor 20, an engine coolant temperature signal provide by a conventional temperature sensor exposed to the engine coolant, and an analogue signal representing the position of the throttle blade 24 provided by a position sensor 36. The position sensor 36 may take the form of a potentiometer driven by the output shaft of the servomotor 30 and whose output is representative of the angular position of the throttle blade 24. The various analogue signals are converted to digital signals by the analogue-to-digital converter 32 upon command of the engine control computer 28. The digital values are stored in a random access memory in the engine control computer 28 for use in controlling the fuel injector 26 and for controlling the position of the throttle blade 24.

The engine control computer 28 further receives a pulse input representing the engine RPM from a conventional ignition distributor and a pulse input (SPD) representing vehicle speed from a conventional speed sensor provided in the vehicle transmission. The engine speed pulses (RPM) are provided once each intake event and functions to initiate operation of the fuel injector 26 which provides a pulse of fuel for each intake event of the internal combustion engine 10. The RPM signal is further utilized to determine the speed of rotation of the internal combustion engine 10. Similarly, the vehicle speed signal (SPD) is utilized to determine vehicle speeds which is utilized when the engine controller is establishing a commanded vehicle speed during a cruise control operating mode of the apparatus. A discrete input (P/N) representing a neutral state (park and neutral gearshift positions) of the conventional vehicle automatic transmission is also provided to the engine control computer 28. This signal (P/N) may be provided as is well known such as by a switch that is actuated when the transmission gear selector is in park or neutral.

The output of the engine control computer 28 is a timed pulse to the fuel injector 26 having a width calculated to provide the quantity of fuel commanded by the position of the accelerator pedal 12. Additionally, the engine control computer 28 provides a digital signal to a digital-to-analogue converter 37 representing a commanded throttle blade position determined to produce a desired mass airflow into the internal combustion engine 10 resulting in a desired air/fuel ratio. The output of the digital-to-analogue converter 37 is provided to a throttle position servo 38. The throttle position servo 38 responds to the commanded throttle position provided via the digital-to-analogue circuit 37 and the actual position of the throttle blade 24 provided by the position sensor 36 to supply a signal to the servomotor 30 to position the throttle blade 24 to achieve the commanded throttle position.

The operation of the engine control computer 28 for controlling the fuel injector 26 and for positioning the throttle blade 24 and for controlling the normal or back-up operating mode in accordance with the principles of this invention is illustrated in the Figures 3 and 4. The routines illustrated in these Figures are executed at repeated intervals such as 10 millisecond intervals. First referring to Figure 3, the program begins at step 40 and proceeds to a step 42 where the engine control computer 28 reads and stores the various input values and discrete signal states. Included at this step 42 is the sequential reading and storing of the analogue inputs to the analogue-to-digital circuit 32 in memory locations in the engine control computer 28. Thereafter, the program proceeds to a decision step 44 where the magnitude of the pedal force sensed by the force sensor 20 and stored at step 42 is compared to zero. If the pedal force is greater than zero indicating the operator is applying force to the accelerator pedal 12 to command a desired off-idle fuel flow, the program proceeds to step 46 where a timer storing a time value T is cleared, the

time T representing the duration of a sensed fault condition. Next, a normal fuel control routine (normal fuel control means) is executed at step 48 where the fuel pulse width to be injected with each intake event of the internal combustion engine 10 is determined and the corresponding throttle position is established. The fuel pulse width is then set into an output counter in the engine control computer 28 and issued with each RPM signal corresponding to each intake event. The desired throttle position is provided to the throttle position servo 38 via the digital-to-analogue converter 37.

The normal fuel control routine of step 48 is more particularly illustrated in Figure 4. Referring to this Figure, the normal fuel routine is entered at a point 50 and proceeds to a decision step 52 to determine whether or not conditions for establishing an engine idle mode exist. In one embodiment, an idle mode condition may be established when the linear potentiometer 18 indicates a released position of the accelerator pedal 12. Assuming an idle condition mode exists, the program proceeds to a step 54 where an idle control routine is established. In general, this routine provides for monitoring the speed of the internal combustion engine 10 and provides for an adjustment of a command fuel pulse width to maintain a desired engine idle speed. This routine may provide for adjustment of the pulse width via proportional and integral control terms as is well known in the control of engine idle speed. This pulse width is set into the output counter in the engine control computer 28 as previously described and issued with each RPM signal for establishing the desired engine idle speed.

Returning to decision step 52, if the linear potentiometer 18 indicates an off idle position of the accelerator pedal 12, the program proceeds to a decision step 56 where the arrangement determines whether or not a cruise control mode has been commanded by the vehicle operator. In general, this mode is commanded by the operator in order to automatically maintain a desired vehicle cruise speed. Assuming the cruise control mode has been enabled by the vehicle operator, the program executes a cruise routine at step 58 that responds to the actual vehicle speed signal and the commanded vehicle speed to adjust the fuel pulse width in a direction to achieve the desired vehicle speed. As with the routine of step 54, the cruise routine may include integral and proportional terms for adjustment of the fuel pulse width to maintain the desired vehicle speed. This pulse is then provided to the output counter in the engine control computer 28 to be issued to the fuel injector 26.

Returning to decision step 56, if the cruise control mode has not been enabled, a step 60 is executed wherein the pulse width to be injected with each intake event of the internal combustion engine 10 is controlled in accordance with the commanded fuel flow represented by the output of the linear potentiometer 18. This pulse width is set into the output counter in the engine control computer 28 and issued to the fuel injector 26 with each RPM signal.

From either of the routines of steps 54, 58 or 60, the program proceeds to a step 62 where the mass airflow required to produce a desired air/fuel ratio is determined. From this step, the program proceeds to a step 64 where the output to the digital-to-analogue converter 37 representing a commanded throttle position is adjusted in accordance with the difference between the actual airflow from the mass air sensor measured at step 42 and the desired mass airflow determined at step 48. This signal may be adjusted in accordance with proportional and integral terms so as to precisely obtain the desired air/fuel ratio. The throttle position servo 38 responds to this commanded signal to position the throttle blade 24 via the servomotor 30 and the feedback signal from the position sensor 36 to achieve a commanded desired mass airflow into the internal combustion engine 10. From the step 64, the program returns to the routine of Figure 3.

Referring again to Figure 3, if decision step 44 determines that the accelerator pedal 12 is in a released position and no force is being applied thereto by the vehicle operator, the program determines whether or not the apparatus is operating in a mode for which this condition is normal. One such mode is the cruise control mode described in regard to Figure 4. Operation of this mode is sensed at decision step 66 (operation sensing means). If the apparatus is operating in a cruise control mode wherein the accelerator pedal 12 force is normally zero, the program then proceeds to the step 46 previously described and thereafter to the normal fuel routine of step 48 which is executed to maintain the desired vehicle speed via the step 58.

If the force applied to the accelerator pedal 12 is zero and the apparatus is not in a vehicle cruise mode, the program determines if the remaining operating mode for which this condition is normal exists. As previously indicated, this mode is the idle mode whereat the engine idle speed is controlled via the idle speed control routine of step 54 of Figure 4. During this mode, the throttle blade 24 position is normally established at some value for maintaining a desired engine idle speed. This normal operation is sensed at decision step 68 which determines whether or not the idle speed command represented by the commanded position of the throttle blade 24 is greater than zero. If greater than zero indicating the idle speed is under control, the program proceeds to the step 46 to clear the

timer T to zero after which the normal fuel routine of step 48 is executed to maintain the desired engine idle speed. However, if a fault condition exists wherein the engine speed is greater than the desired engine idle speed and the idle speed control routine 54 is unable to reduce the engine speed to the desired engine idle speed, the commanded fuel and, therefore, the commanded position of the throttle blade 24 will be reduced until such time that the throttle blade commanded position is set to zero. This fault condition is sensed at decision step 68 by comparing the commanded throttle position provided to the digital-to-analogue converter 37 with zero. If the commanded position is zero indicating the engine idle speed is not under the control of the idle control routine of step 54, the program proceeds to the decision step 70 where the duration of T of the fault condition is compared to a calibration constant K, such as 100 milliseconds. If the fault condition has not existed for the time period K, the time value T is incremented at step 72 and the normal fuel routine of step 48 is executed. However, if the fault condition has existed for the time duration K, the program proceeds to a step 74 (controlling means) where a back-up fuel control routine is executed. During this routine, the fuel pulse width applied to the fuel injector 26 is reduced to some low value to force an engine idle speed condition. The back-up fuel routine of step 74 may also include the control of the mass airflow as per the step 62 and step 64 previously described in order to maintain a desired air/fuel ratio.

The back-up fuel routine is latched in accordance with the preferred embodiment of this invention until such time that the vehicle operator should intentionally shift the vehicle transmission from drive or reverse to park or neutral. This condition is sensed at decision step 76. Assuming the vehicle operator has not shifted from drive or reverse to park or neutral, the program returns to the back-up fuel routine of step 74. This cycle is repeated until such time that the vehicle operator shifts the vehicle transmission to park or neutral. When this condition is sensed, the program exits the routine of Figure 3. This allows the operator to reset the back-up fuel condition. If the fault has been corrected, the normal control of engine fuel and engine air is controlled as previously described. However, if the fault condition continues to exist, the back-up fuel routine of step 74 will again be enabled as previously described.

In the preferred embodiment of the invention, a fault condition was sensed at decision step 68 when the commanded throttle position became zero indicating the idle speed control routine not in control of the engine speed. Other parameter may be utilized to sense this fault condition. For example, in one embodiment, the fault condition may be represented by the engine torque output being greater than some predetermined value (which may be a function of temperature). This torque output may be represented by the product of engine speed and the injector pulse width. Alternatively, the fault condition may be represented by a value of engine (which may be a function of engine temperature) that is greater than the engine idle speed at that temperature.

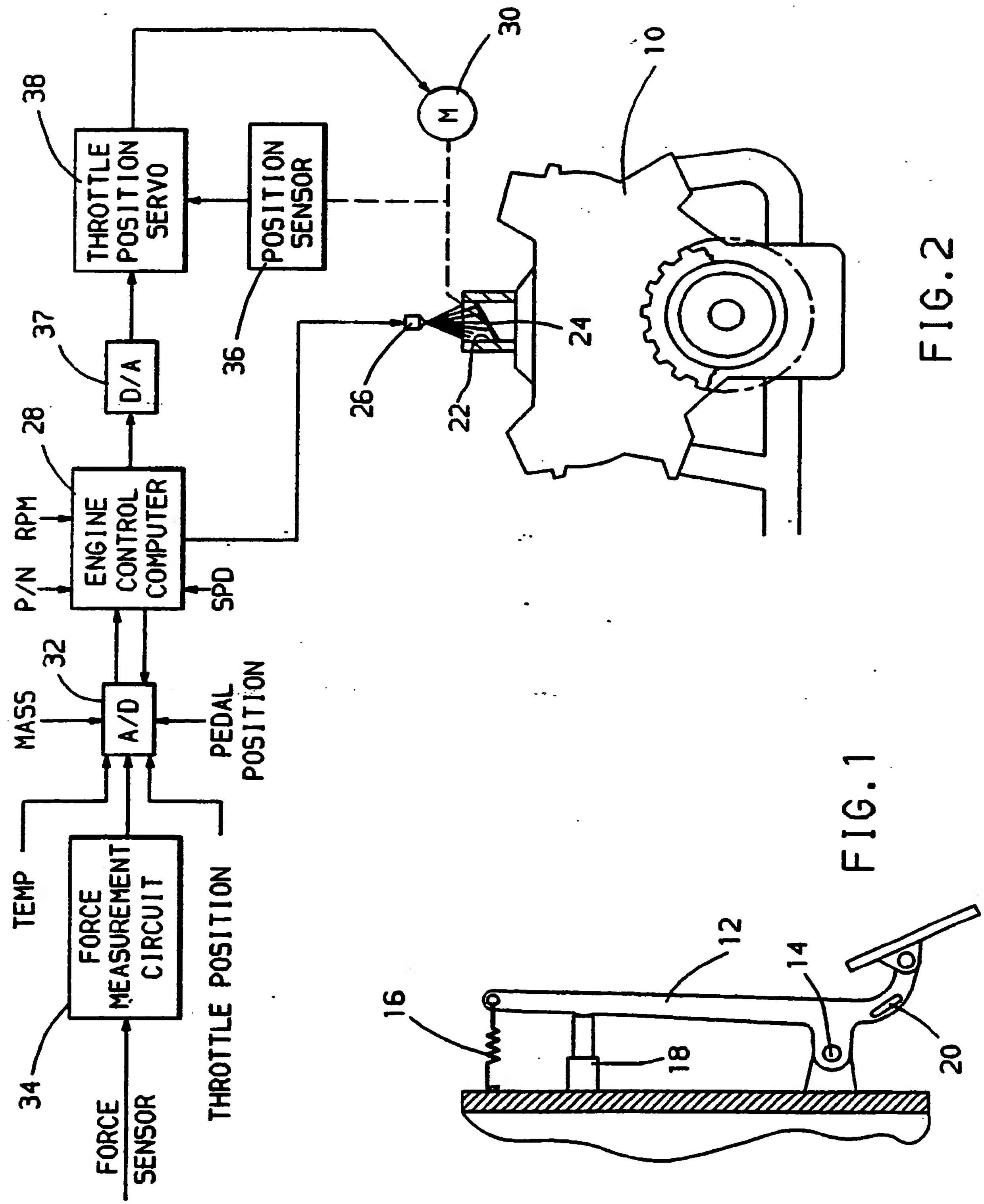
Claims

1. An engine controller for an internal combustion engine (10) of a vehicle, the internal combustion engine having an intake space into which air and fuel are supplied, the engine controller comprising in combination: an accelerator pedal (12) biased to an engine idle position and operable to an engine off-idle position in response to a force applied thereto; and position sensing means (18) for sensing the position of the accelerator pedal (12) established by force applied thereto; characterised by force sensing means (20) for sensing the force applied to the accelerator pedal (12); normal fuel control means (48, Fig. 4) selectively operable (A) in a first mode for controlling the air and fuel mixture in accordance with the accelerator pedal position sensed by the position sensing means (18) and (B) in a second mode for controlling the air and fuel mixture in response to a predetermined operating condition independant of the accelerator pedal position, the force applied to the accelerator pedal (12) being normally zero in the second mode; operation sensing means (66) for sensing selected operation of the normal fuel control in the second mode; and controlling means (74) for controlling the air and fuel mixture to a predetermined amount independent of the normal fuel control means (48, Fig. 4) in the absense of a sensed selected operation of the normal fuel control in the second mode when the force applied to the accelerator pedal (12) is zero.

2. An engine controller as claimed in claim 1, wherein the second mode is a cruise control mode wherein the air and fuel mixture is controlled to maintain a predetermined speed of the vehicle.

3. An engine controller as claimed in claim 1 or claim 2, wherein the normal fuel control means (48, Fig. 4) includes idle speed control means (54) responsive to an idle position of the accelerator pedal (12) and engine speed (RPM) for adjusting the air and fuel mixture in direction to maintain a predetermined engine idle speed; and the engine controller further includes sensing means for (A) sensing a predetermined value of the idle speed control means adjustment of the air and fuel mix-

ture in direction tending to reduce engine speed when the sensed force applied to the accelerator pedal (12) is zero, the predetermined value representing the engine speed not being under the control of the idle speed control means and (B) actuating the controlling means (74) to control the air and fuel mixture to a predetermined amount independent of the normal fuel control means.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FORCE MEASUREMENT CIRCUIT
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MASS
32
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PEDAL POSITION
P/N
RPM
28
ENGINE CONTROL COMPUTER
SPD
37
D/A
38
THROTTLE POSITION SERVO
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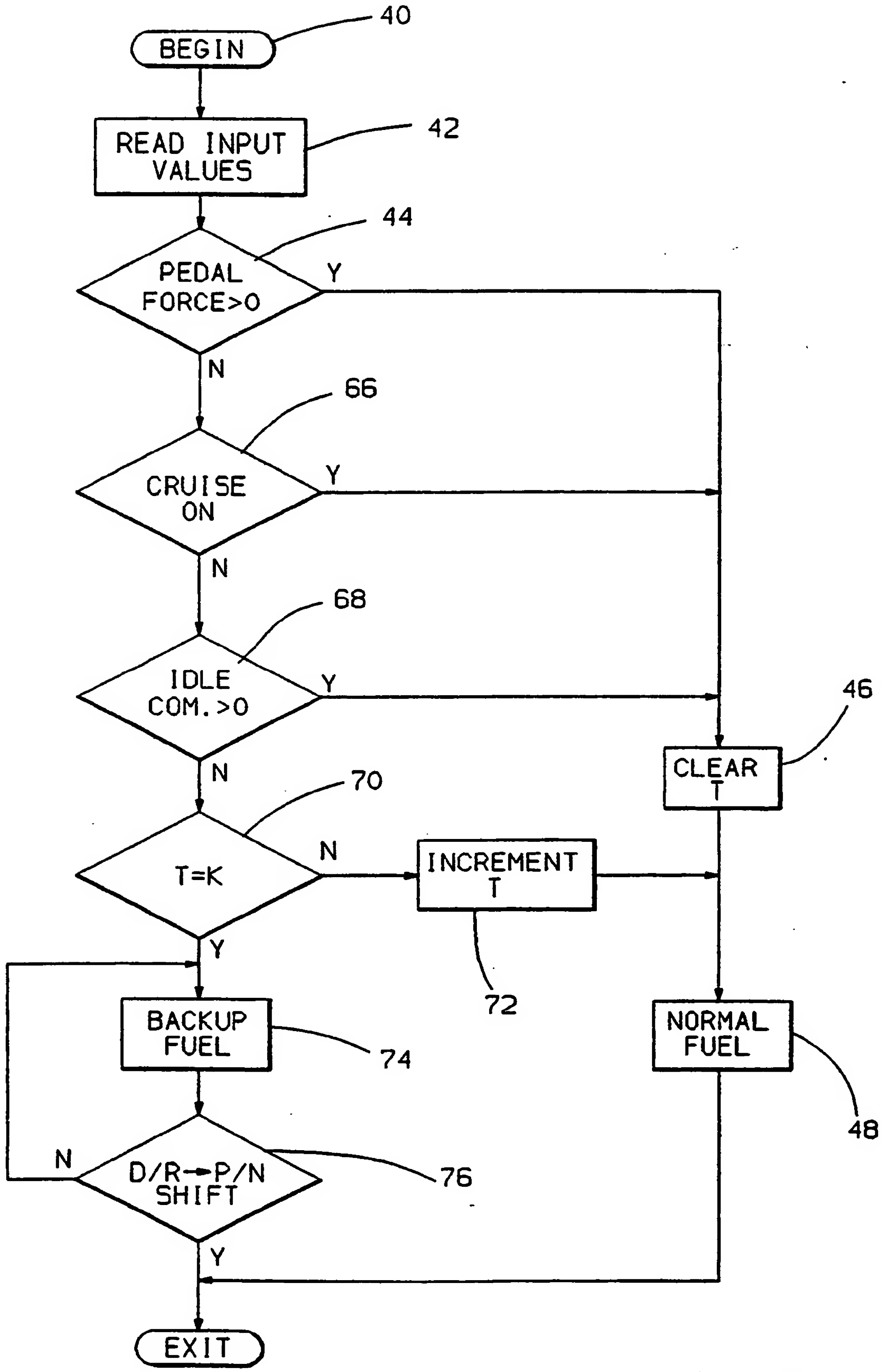
POSITION SENSOR
30
M
10
26
22
24
16
12
14
18
20

FIG.1

FIG.2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44
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N
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N
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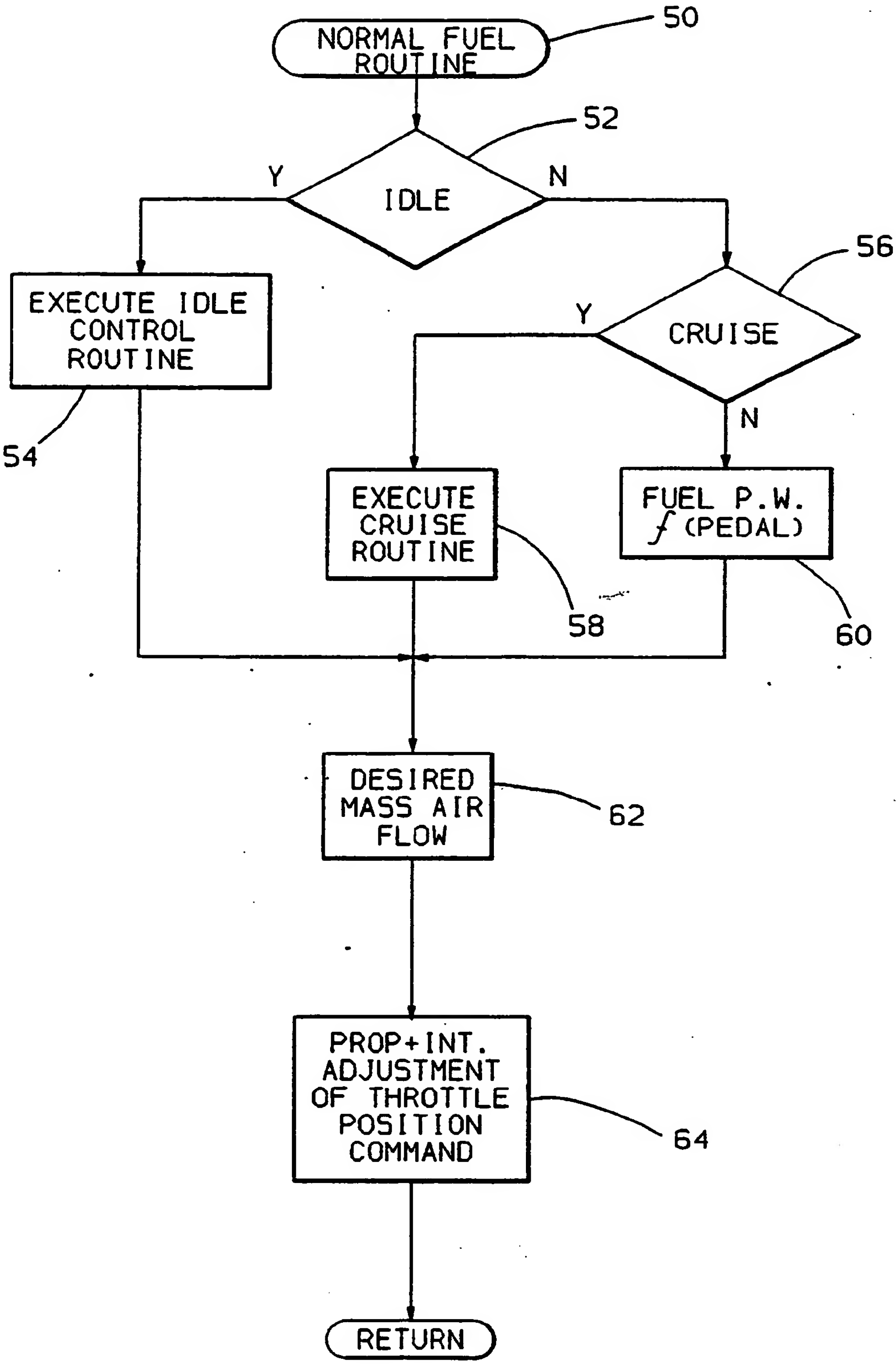
IDLE COM.>0
Y
N
46
CLEAR T
70
T=K
N
INCREMENT T
72
Y
BACKUP FUEL
74
NORMAL FUEL
48
N
D/R→P/N SHIFT
76
Y
EXIT

FIG.3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50
52
IDLE
Y
N
EXECUTE IDLE CONTROL ROUTINE
54
56
CRUISE
Y
N
EXECUTE CRUISE ROUTINE
58
FUEL P.W. ƒ (PEDAL)
60
DESIRED MASS AIR FLOW
62
PROP+INT. ADJUSTMENT OF THROTTLE POSITION COMMAND
64
RETURN

FIG.4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 30 6940

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	US-A-4569425 (EATON CORP.) * figures 1, 5 * * column 6, line 48 - column 7, line 51 *	1-3	F02D11/10 F02D41/22
X	US-A-4225007 (FRED W.VOGES) * figures 1-3 * * column 2, line 8 - column 3, line 55 *	1, 2	
D,X	US-A-4640248 (GENERAL MOTORS CO.) * figures 1-3 * * column 1, lines 37 - 60 *	1	
A	GB-A-2133906 (ROBERT BOSCH GMBH.) * figures 1, 5 * * page 1, lines 75 - 86 * * page 2, lines 33 - 53 * * page 3, lines 9 - 23 *	1, 3	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F02D B60K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	04 DECEMBER 1989	LAPEYRONNIE P.J.

CATEGORY OF CITED DOCUMENTS

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